# Negative heat capacities in Au multifragmentation?

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Recently, a measure of heat capacity has been put forth to address the issue of the existence of a phase transition in nuclear multifragmentation [1, 2]. Using the EOS gold on carbon data set [3] an estimate of this heat capacity was made following those efforts.

The total energy was separated into kinetic and potential energy partitions: $m_0 + E^*_{th} = E_1 + E_2$; $m_0$ is the mass excess of the remnant and $E^*_{th}$ is the excitation energy. The potential energy is $E_2 = \sum_{i=1}^{M} m_i + E_{Coul}$; $M$ is the total (charged and neutral) multiplicity of the primary fragment distribution, $m_i$ is the mass excess of the $i^{th}$ fragment and $E_{Coul}$ is the Coulomb energy. Solving for the kinetic energy gives $E_1 = E^*_{th} - E_{Coul} + Q$; $Q$ is the summation of the removal energies of the event. The estimate of $M$ was made from a model calculation based on the Statistical Multifragmentation Mode (SMM). The estimate of the Coulomb energy was made following the SMM and assuming a final state volume based on the isentropic expansion of a Fermi gas [3].

Next, the *microcanonical* temperature $T_\mu$ was determined by separating the kinetic energy $E_1$ into its components [2]

$$\langle E_1 \rangle = \left\langle \sum_{i=1}^{M} a_i \right\rangle T_\mu^2 + \left\langle \frac{3}{2}(M-1) \right\rangle T_\mu \qquad (1)$$

where brackets indicate the average of a quantity in a bin of $E^*_{th}$. The level density parameter was assumed to be $a_i = 1/13$ [3]. $T_\mu$ was determined by solving the quadratic equation in Eq. (1).

Taking the derivative of Eq. (1) with respect to $T_\mu$ gives the heat capacity of partition one as

$$C_1 = \frac{\partial E_1}{\partial T_\mu} = 2\left\langle \sum_{i=1}^{M} a_i \right\rangle T_\mu + \left\langle \frac{3}{2}(M-1) \right\rangle . \quad (2)$$

This relation implies either a constant volume or a constant pressure.

The heat capacity of the entire system was determined via $C \sim C_1^2/(C_1 - \sigma_1^2/T_\mu^2)$ . At some intermediate region of $E^*_{th}/A_0$ the heat capacity, normalized to the size of the fragmenting remnant, shows a negative region. See Fig. 1a.

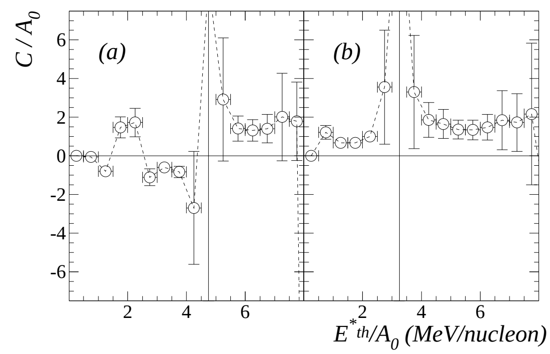


Figure 1: (a) Heat capacity with initial estimates of $E_{Coul}$, $Q$ and $M$. (b) Heat capacity with altered estimates of $E_{Coul}$, $Q$ and $M$.

This analysis rests on assumptions concerning unmeasured quantities, e.g. $E_{Coul}$, $Q$ and $M$. If the $E_{Coul}$ is 50% lower than above, then $C > 0$ always, or if all of the unmeasured quantities are 20% lower than the above estimates, the negative heat capacity disappears, see Fig. 1b. Therefore, the systematic error bars for this heat capacity diverge in the region where the signal is of interest and the presence of a negative heat capacity is questionable.

## References

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[3] J. A. Hauger *et al.*, Phys. Rev. C **57**, 764 (1998).